

## The Limit of Gene-Culture Co-evolutionary Theory

Min-seop Lee

Program in History and Philosophy of Science  
Seoul National University

Dayk Jang<sup>†</sup>

College of Liberal Studies  
Seoul National University

The theories of cultural evolution hold subtly or clearly different stances about definition of culture, pattern of cultural evolution, biases that affect cultural evolution, and relationship between culture and organism. However, the cultural evolution theories have a common problem to solve: As the evolutionary theory of life tries to explain the early steps and the origin of life, the cultural evolution theories also must explain the early steps of the cultural evolution and the role of the human capability that makes cultural evolution possible. Therefore, explanations of the human's unique traits including the cultural ability are related to determine which one is the most plausible among many cultural evolution theories. Theories that tried to explain human uniqueness commonly depict the coevolution of gene (organism) and culture. We will explicitly call the niche construction theory and the dual inheritance theory the 'gene-culture co-evolutionary theory'. In these theories, the most important concept is the 'concept of positive feedback'. In this paper, we distinguish between core positive feedback and marginal positive feedback, according to whether the trait that the concept of positive feedback explains is the trait of human uniqueness. Both types of positive feedback effectively explain the generality of human uniqueness and the diversity of human traits driven by cultural groups. However, this positive feedback requires an end, in contrast to negative feedback which can be continued in order to maintain homeostasis. We argue that the co-evolutionary process in the gene-culture co-evolutionary theories include only the positive feedback, not covering the cultural evolution after the positive feedback. This thesis strives to define the coevolution concept more comprehensively by suggesting the potential relationships between gene and culture after the positive feedback.

*Key words : cultural evolution, gene-culture co-evolutionary theory, human uniqueness, dual inheritance theory, niche constructionism, core positive feedback, marginal positive feedback*

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<sup>†</sup> Corresponding author: Dayk Jang, College of Liberal Studies, Seoul National University  
E-mail: [djang@snu.ac.kr](mailto:djang@snu.ac.kr)

## Introduction

The theories of cultural evolution subtly vary according to definition of culture, pattern of cultural evolution, biases that affect cultural evolution, and relationship between culture and organism. However, all cultural evolution theories must explain the phylogenetic features of human, such as the cultural ability in the early days. Explanations of human uniqueness are also related to the solutions to the cultural evolution theories. Moreover, the cultural evolution theory about the relationship between gene and culture is necessary to explain human uniqueness such as early social learning abilities and early culture. Since the cultural evolution theory and the topic of human uniqueness coexist to solve each other's questions, the two cannot be examined individually.

The cultural evolution theories that examine the evolutionary relationship between the organism and the culture by introducing the two types of inheritance system of gene and culture, consists of dual inheritance theory[1], niche constructionism[2, 3, 4], and meme theory[5, 6, 7]. The meme theory views culture as a completely independent replicator, while the other two view that culture is more associated with genetic evolution. The question of independence of culture and genetic evolution should be solved by looking at human evolution.

According to dual inheritance theory and niche constructionism, the co-evolutionary concept is the most important in cultural evolution. Therefore, the two theories will be called the 'gene-culture co-evolutionary theory'(hereafter, co-evolutionary theory). The structure of the co-evolutionary theory is as follows: An organismic change causes a cultural change, and this change causes another organismic change in a new generation. The modified organism then again causes a modified culture, establishing a reciprocal action between the two. This interaction is called the 'positive feedback' which can also be used to explain other natural phenomena.

The two theories differ in detailed matters, but the two are the same theory from the co-evolutionary perspective. Therefore, it is essential to analyze the co-evolutionary theory with another criterion for discussion. We will distinguish between core positive feedback and marginal positive feedback by looking at whether or not the traits resulted by positive feedback processes point toward human uniqueness. While the core positive feedback is a process necessary for the evolution of unique human traits, while the marginal positive feedback is a process necessary for the evolution of traits other than human uniqueness.

The explanations through the two positive feedbacks play an important role in the emergence of

human universality and diversity in the hominin lineages. However, will that there is a limit in describing the coevolution of gene and culture solely with the positive feedback. This limit roots from a special of the positive feedback. The positive feedback helps a certain condition to quickly reach a steady level - when a certain condition reaches a level, the positive feedback ends. When the positive feedback is terminated, the elements forming the positive feedback can play in other kind of interactions.

When dealing with the relationship between culture and organism, the dual inheritance theory and the niche constructionism apply the two types of positive feedback processes view the coevolution only through the lens of positive feedback; therefore, they cannot fully explain the cultural evolution after the feedback. The phenomena between gene and culture should be studied more comprehensively by expanding the concept of coevolution itself. we will relationships other than positive feedback included in the concept of coevolution. Those include symbiosis, competition, parasite, and indifference; these relationships not only exist between organisms but also between gene and culture. In the next , we will explain the reasons cultural evolution theory and human uniqueness problem have to be dealt with together.

## **Cultural evolution theory and the human uniqueness problem**

### **2.1. The culture and its evolution play an important role in evolution of the human uniqueness**

Primatologists typically run a comparison test between human and non-human animals(hereafter, animals) in studying the evolution of social learning abilities. Countless comparison tests prove that there is a systematic difference in quantity and quality of social learning abilities between humans and animals. For animals, there are no active form of teaching and learning; active teaching and learning is only possible when one can share the information of their behavior. Animals do not have the ability to share the information of their behavior or motion. Although they cannot deliberately share behavioral information, they can learn from the behaviors of another animal. However, there are still restrictions. Animals could imitate actions when the other's action was the purpose, but could not imitate the order and the procedure of the action itself. Some primatologists then conclude that animals cannot have a collected culture, since they could not accurately imitate the procedure of

an action[8].

The comparative studies of social learning abilities clearly show the differences between humans and animals; however, they do not effectively explain how those differences became to exist. Some investigators attempt to explain the differences by points such as the size of the group or alliance which is correlated to social learning skills[9]. Nevertheless, social learning ability cannot be explained so simply; unless we trace the cause and effect of the sources, we cannot have a sufficient explanation of social learning ability.

Social learning ability is a complex skill that involves the culture made by reading others' intentions and working with others. To fully understand the evolution of social learning abilities, we need to examine other unique features of humans. Bingham recognized these complex features intertwined with each other, and called this the "Human Uniqueness Problem"[10, 11]. The reason why this problem is hard to solve is because it includes the question of "How did these complex features emerge?" and "How did these features evolve so *quickly* in a short period of time?" in this problem.

In order to successfully explain the evolution of human uniqueness, we need to intuitively solve two problems. First, how could human effectively acquire resources from the nature? Second, how did human make a selection pressure that is strong and consistent? These two questions are important because of the fast speed of human evolution. It has been 6 million years since mankind separated itself from the common ancestor with chimpanzees. This is a very short period in an evolutionary perspective, but the phenotypic differences between humans and chimpanzees are massive. An effective gain of resources and continuous pressures to evolve account for the rapid evolution of human. An effective gain of resources is like fuel to evolution. A large-scale cooperation and cooked food enabled humans to use the natural resources effectively. However, fuel is not sufficient to continue the process of evolution. Selection pressures, in addition, are like an engine that drives evolution. Evolution could be possible because humans had the ability to make their own selection pressures continuously. Then, the question is, do these two play together or separately?

Bingham suggested a "coalitional enforcement" as the key to solve the human uniqueness problem[10, 11]. He argues that the coalitional enforcement does a good job explaining social cooperation among non-relatives. The coalitional enforcement refers to enforcing behaviors of a specific entity by forming a coalition between other entities. In order for a coalitional enforcement to work, cooperation between entities is necessary. Moreover, a technological development and a long-distance weapon are also necessary for the enforcement. Before the evolution of long-distance weapons and

their usage, the cost to coalitionally enforce one another was considerably high. This was because the one who was enforced often was more physically dominant, and a close attack could result in a lot of casualties. Therefore, a weak individual among the coalition is easily tempted to withdraw from the coalition, which makes the coalition fragile.

The evolution of long-distance weapons, on the other hand, enables one to attack simultaneously from far away. Therefore, the cost of sacrifice became negligible. The coalition is also stronger, free from temptations to withdraw, since those who withdraw could be the target of the next coalitional enforcement. The coalitional enforcement could have not existed without the physical evolution of standing upright and walking, because it enabled one to effectively throw a stone weapon or strike with a pointy stick. Moreover, coalitional enforcement is only possible if one has the ability to produce tools along with the ability to use them. A non-kin group based on the coalitional enforcement activates the exchange of non-genetic information among the members of the society, which influences the development of language, intelligence, and morality. According to Bingham, humans were able to form a bigger coalition as the technology of making long-distance weapons advanced.

The coalitional enforcement effectively explains the unique features of humans including social learning. This may be confined to the development of long-distance weapons, but a cultural element made by social learning leads the evolution of the organisms to a certain way. However, Bingham's explanation lacks in a way that it does not thoroughly describe the process of cultural elements influencing the evolution of organisms, and that it fails to recognize the cultural aspects such as the accessories or symbols that represent the group, aside from long-distance weapons. In order to explain the evolution of human uniqueness, we need to investigate into both long-distance weapons and other cultural aspects, and how those elements influenced the evolution.

## 2.2. The true cultural evolution theory must solve the human uniqueness problem

When looking into cultural evolution, many cultural evolutionary theories investigate how a culture evolves, assuming a high level of social and cultural learning abilities. This can be proven looking at how scholars with different opinions on cultural evolution theories define culture. Richard Dawkins, who proposed the meme theory, viewed culture as a replicator. He argued that culture, the replicator, is passed on through imitation [5]. Dawkins' definition of culture implies that culture requires the ability to imitate, in order to evolve through natural selection. In dual inheritance

theory, another type of the gene-culture co-evolutionary theory, defines culture as information that can influence the behavior of an entity by learning from another entity of the same kind through learning, imitation and other methods of social communication[1]. dual inheritance theory, except the fact that it also talks about social learning skills other than imitation, also models how the frequency of cultural information changes based on an already significantly evolved social learning abilities.

These approaches, however, often neglect the fact that culture, as organisms, has gradually evolved over time. Culture and life have developed in an indistinct and ambiguous form, unlike from what we think. It was Darwin's great achievement to find this theory in the complexity and diversity of life. If that is the case, why don't we start the discussion of cultural evolution from the most basic form of culture? Why do gene-culture theorists start the discussion from a developed culture?

Even if we only investigate the cultural evolution subsequent to the development of social learning abilities, there are still some issues that need to be considered. The issues are as follows: Can cultural evolution be explained only through introducing the same particle as the replicator?[1, 5, 12, 13] Is the process of social transmission really considered as a replication as the replication of genes?[5, 7, 12, 14, 15] In the process of social transmission, does a human's unique cognition process influence the transmission? [1, 12, 16]. However, these issues lack questions like "How did a social learning ability evolve?" or "What was the primitive form of culture?" As many modern biologists study molecular biology, genetics, embryology, and evolution after they have accepted the fact that the DNA-based life became the only adapted life form on the earth, similarly, cultural evolution theorists might study the cultural contents and pattern transmitted through social learning after accepting that social learning ability is a form of adaptation.

However, just because biologists are uninterested in the life forms before DNA-based organisms, it does not mean that cultural evolution theorists should forget about the primitive forms of culture. The primitive forms of life and the primitive forms of culture are different in many ways. First is an ontological difference; unlike in the case of organisms, there exists an inheritance between organism and culture in the evolution of culture. Cultural evolution theories must deal with the two inheritance structure to begin with. Secondly, from an explanatory point of view, the evolution of DNA structure does not require a complex adaptive explanation, but the evolution of social learning abilities requires an accurate adaptive explanation, because there is a big difference in the complexity of the two forms. The third difference is resulted by the combination of the first two differences; an adaptive explanation of the evolution of social learning abilities require a primitive level of culture and its inheritance structure. Lastly, in an instrumental perspective, the understandings of the

primitive life forms before DNA, although it is very important in completely understanding the history of life, does not influence the study of contemporary biology based on DNA. On the other hand, understanding the primitive forms of culture, their inheritance structure and the evolution of organisms can help piece together the complicated issues of cultural evolution theories.

As discussed before, cultural evolution theory must deal with the primitive forms of social learning ability and culture. In explaining such uniqueness, the human uniqueness problem requires a theory about the relationship between gene and culture. Therefore, cultural evolution theory and human uniqueness problem should not be investigated separately because one requires the other to solve their own problems.

### **Co-evolutionary Theory and Positive Feedback**

3.1. Many cultural evolutionary theories use the concept of coevolution to explain human uniqueness.

The previous section examined the reason why cultural evolution theory and human uniqueness problem should be investigated simultaneously. In short, this is because culture and organism are intertwined and influenced the evolution of one another. This section will introduce the original theories that explain the evolution of gene and culture and closely examine coevolution and positive feedback which could solve the problem of human uniqueness.

The gene-culture coevolutionary theory, that examines the evolutionary relationship between the organism and the culture by introducing the two types of inheritance structure of gene and culture, consists of dual inheritance theory, niche constructionism, and meme theory. The meme theory views culture as a completely independent replicator, while the other two view that culture is more associated with genetic evolution. The question of independence of culture and genetic evolution should be solved by looking at the evolution process of human.

Blackmore developed Dawkins' meme theory by combining it with the human uniqueness problem[6](Blackmore 2000). Blackmore considers the birth of meme as a very important event in the history of human evolution and illustrates the process of memetic drive through the very first imitation (with a very low level of duplicating accuracy). Blackmore hypothesizes that the very first meme was advantageous to the life and reproduction of organisms. Without much effort, people can

acquire these favorable patterns of behavior by imitation. Eventually, people close to the first imitators realize the benefits that the imitators acquire and imitate them and choose them as their partners. As there are more behaviors through imitation, the distinction between different levels of imitation ability becomes clear. One has to imitate the best imitator, and one has to choose that person as the sexual partner. Because the two factors -- the ability to imitate and the size of the brain -- are correlated, the infancy of human is longer than others in order for the brain to develop and to imitate the best one. Blackmore concludes that this is why those who could imitate better have survived and the world has become a better environment for the meme.

Blackmore's explanation, however, only consists of imitation abilities among other human uniqueness; it does not quite explain the other cognitive abilities or cooperative abilities. Yet, we would like to focus on the fact that her explanation pictures the coevolution of the imitation abilities of culture and organisms. This is very structurally similar to how dual inheritance theory and niche constructionism argue about the relationship between gene and culture.

According to dual inheritance theory and niche constructionism, the co-evolutionary concept is the most important in a cultural evolution. That's why two theories are called the 'co-evolutionary theory' here. The structure of the co-evolutionary theory is as follows: An organismic change causes a cultural change, and this change causes another organismic change in a new generation. The modified organism then again causes a modified culture, establishing a reciprocal action between the two. This interaction is called the 'positive feedback' which can also be used to explain other natural phenomena.

### 3.2 Marginal positive feedback and Core positive feedback

In regards to the definition of positive feedback, W. R. Ashby argued that mathematicians and theorists prefer defining feedback as the “circularity of action”; for a more practical goal, feedback must be a purposeful effect[17]. He criticizes the “circularity of action” definition because it is not practical. According to such definition, the movement of a pendulum has to be considered a feedback since the increase of the momentum results in the increase of position, and the increase of position then results in the increase of the momentum.

A. Ramaprasad defined feedback as the information that is used in changing the differences between the reference level of a system parameter and the actual level of a system parameter[18]. He defined feedback as an information, but argued that an information that is not transformed to a



specific action is not considered a feedback.

The biggest difference between dual inheritance theory and niche constructionism is the definition of culture. Dual inheritance theory views culture as an information in the brain[1]. Such clear definition of culture is very useful in modeling a formula simulating the frequency change of information, and the dual inheritance theorists frequently use this method.

Defining culture as information in the brain could seem too general, but it is not always the case considering the history of human evolution. “Information in the brain” implies that the information can move between individuals through communication. This means that cultural evolution can only begin when humans are able to deliver the information. This ability is one of the most unique traits of human. If we say that culture depends on this ability, the influence caused by cultural evolution before the development of social learning ability is considerably limited.

On the other hand, Niche constructionism views a world that is engineered by the organism and that is inherited as culture[2, 3, 4]. The strength of this definition is that it can start with the primitive forms of culture and examine the evolution of human uniqueness.

Although the two theories both examine coevolution, they have different areas of interest because they define culture differently. Dual inheritance theory studies the coevolution of gene and culture after the development of human uniqueness, while niche constructionism study the coevolution before that the development as well. To compare the two, niche constructionism is considered to be more comprehensive. However, it does not mean that dual inheritance theory does not explain the human uniqueness at all. Dual inheritance theory is a very stable way to investigate in that it provides a quantitative analysis in many other important traits other than human uniqueness. Therefore, the unique traits can be explained by niche constructionism and other traits can be explained by dual inheritance theory.

The two theories share more similarities than differences. Therefore, for discussion, there is a need to distinguish different phenomena of coevolution with a new standard. In human evolution, the positive feedback of culture and organism will be divided into marginal and core positive feedback depending on whether or not their traits include human uniqueness. Marginal positive feedback is a process necessary for the evolution of traits other than human uniqueness, and core positive feedback is a process necessary for the evolution of human uniqueness traits.

### 3.2.1. Marginal positive feedback

For a human baby who consumes milk, the body needs to produce enzymes that could help

digest lactose. However, before the start of dairy production, most human societies did not consume milk, which stops such enzymes from being produced. Some adults cannot digest milk because the enzymes that help digest lactose are not produced anymore. However, since the production of dairy, milk became a consumption for adults as well as children, which led to the spread of a mutant gene that did not stop producing the enzymes. This spread brings a positive influence to the dairy production culture, and this relationship forms a positive feedback. The dairy production culture is an independent structure that is inherited from social learning, rather than from genetic information.

The previous example that pointed out the coevolution of lactose-digesting enzymes and dairy production is a paradigmatic example of dual inheritance theory. This could also be a model of marginal positive feedback, because there is no core difference between cognitive abilities of humans that have the lactose-digesting enzymes and humans who do not. We have different kinds of culture other than dairy farming, and according to each culture, the genetic traits respond. Therefore, marginal positive feedback continues to exist locally in the human race until the present day.

### 3.2.2. Core positive feedback

In *The Evolved Apprentice* (2012), Sterelny who argues for niche constructionism, comes up with a general explanation about human uniqueness[19]. He emphasized the “apprentice learning model” and the positive feedback process, which includes not only the elements of organisms but also the outside environment. The positive feedback process that he suggested is the most general core positive feedback process that explains human uniqueness.

Sterelny divides the feedback loop into two. First loop is between expertise, social learning and life history, and second loop is between expertise, individual adaptations for social learning, and organized learning environments. He argues that the first feedback loop has been widely accepted despite the fact that it is debatable, and the second loop that includes systemized environment has been ignored. Let us dive into the two core positive feedback loops that Sterelny proposed.

#### 3.2.2.1. ‘Life history and cooperation’ feedback loop

The first loop explains the unique human life history and cooperative abilities that exist between relatives and non-relatives. The evolution of cooperation plays an important role in efficiently extracting resources from the nature. For example, many people cooperated in hunting and gathering. Moreover, human parents have to divide work because of the long childhood of humans and often have to adapt communal childcare with the relatives. Humans also cooperate by sharing information

about hunting and gathering or local environments within a society. Sterelny argues that the evolution of cooperation emerged through the human life history and informational cooperation.

Let us now examine in detail how cooperation and the feedback loop of human life work together. The human life history and cooperation feedback loop is composed with three factors: the change of life history, the informational cooperation, and expertise. Ecological cooperation and reproductive cooperation will be placed in between the three factors. It is not easy to find the starting point of the positive feedback loop, because of its inherent nature. Therefore let us start from the informational cooperation.

1) Informational cooperation → expertise

To begin with a weak level of informational cooperation, informational cooperation can be referred to as informational flow within and in between generations. Informational cooperation helps to spread the professional skill within a society. This expertise can be information about the local environment for foraging or it could be information about using the environment. When a pool of information is created and if that could flow among generations, there soon could be specialization and differentiation of labor. This type of informational cooperation requires a social learning skill.

2) Expertise → the change of life history

The pile of expertise helps to efficiently forage. Through efficient foraging, humans could gain a lot of energy. As many expertise become diverse, ecological cooperation is necessary for an efficient hunting and gathering. The extra energy acquired through efficient foraging is inherited to the younger generation. Children and teenagers could learn useful skills to hunt. Expertise helps to raise the ecological suitability for those who have the information. According to the ecological suitability, the probability of survival and life expectancy increases. Now one needs to invest time learning more and more expertise. The selective pressure of long childhood gets bigger as children need more time to learn. As childhood becomes longer, it gets harder to raise one child. This leads to reproductive cooperation of the parents as they need to provide to the child; there also could be a reproductive cooperation of the relatives as they raise the child together.

3) The change of life history → informational cooperation

As the life expectancy increased, the number of information one can store during lifetime also increased. When a generation has many information to store, it means that the next generation has

a lot to learn. The extension of life expectancy and childhood promotes the flow of information. With the increased amount of knowledge, humans could experience a more advanced informational cooperation.

### 3.2.2.2. 'Cognition and environment' feedback loop

Sterelny argues that social learning itself emerged before the adaptation for social learning. To support his argument, he proposes phenotypic plasticity and niche constructionism. A change in the response of the genes when there is a small change in the environment can be explained by phenotypic plasticity. In addition, if there is a premise that the organized environment can influence the cognition of human, a change in the environment caused by social learning can play an important role in social learning which is emerged by phenotypic plasticity assimilating into gene adaptation. Let us look in detail at how such processes could happen by analyzing cognition and environment feedback loop.

#### 1) Individual learning abilities → social learning

The starting point from 'cognition and environment' feedback loop is social learning which was emerged without the adaptation for it. Children learn adult's activities through their ecological activities. Such learning could appear through adaptive plasticity, hand agility, and hunting methods that existed prior to the adaptation for social learning. However, the flow of information caused by this process would not have been on the level of the duplicating accuracy and efficiency of the information transfer after the adaptation of social learning.

#### 2) Social learning → organized learning environment

Social learning prevents skills found by a generation from disappearing after that generation. The information flowing into the next generation allows the users to use the technology without much effort. That way, the environment becomes organized by the skills. For example, the technology to build a house and the technology to create a hunting tool using a stone accumulate through generations to generations. A main difference between chimpanzees and humans is that chimpanzees do not have the ability to organize the environment that could affect the organism. They use tools to hunt termites or open nuts and also show social learning, but they do not have the organized nature of accumulating skills.

3) Organized learning environment → individual adaptation for social learning

When an organized learning environment forms, there will be a genetic mutation to learn from high reliability and efficiency of others. In other words, there will be an adaptation for social learning. Genetic mutations for learning more accurately from the parents will survive. This process of adaptation should involve informational cooperation such as parents allowing their children to have access to their possessions and making their children a practical tool.

3.2.2.3. Two core positive feedback loops and apprentice learning model

So far, life history-cooperation loop and cognition-environment feedback loop would have worked together. The two loops are intertwined in terms of informational cooperation and social learning. Informational cooperation is a wheel that comprise of 'life history and cooperation loop' and social learning ability is a wheel that comprises 'cognition and environment' loop. In 'life history and cooperation' loop, social learning ability is necessary, and in 'cognition and environment' loop, informational cooperation is necessary. Even a highly advanced informational cooperation is useless if the cognition ability is weak, and a highly advanced cognition ability is useless if there is no motivation to cooperate and share information. In other words, each element of the feedback loop is a fuel to the other elements of the loop.

Since the two feedback loops are intertwined in aspects of informational cooperation and social learning abilities, this part is very important. The apprentice learning model that has been proposed by Sterelny includes both informational cooperation and social learning abilities. The main idea of the model is open attitude towards apprentices and acts of learning through observing adults. In other words, the evolution through positive feedback and apprentice learning model cannot be considered individually, and therefore the apprentice learning model should be in the center of the feedback loop.

The two feedback loops are attached together through the apprentice learning model, because social learning ability is the most important aspect in apprentice learning among the loop of 'life history and cooperation' and the loop of 'cognition and environment.' Moreover, in the loop of 'cognition and environment', social learning abilities not only mean social learning but also mean hybrid learning including individual learning through trial and error. The two loops do not move independently, and they show how one trait causes another within evolution process. These loops constantly depend on each other during the evolution process, and in the center of that, there exists the apprentice learning model.

### Limit of positive feedback

So far we have examined positive feedback, focusing on cases where the two types of positive feedback are applied. Core positive feedback explains how the unique traits of human and culture evolved from a primitive form to a complex form. On the other hand, marginal positive feedback focuses on the evolution of traits other than human uniqueness after a certain level of social learning abilities. Through this process, there could be a lot of fast genetic and cultural modifications. The two feedback processes effectively explain the quick appearance of universality and diversity of humans.

From now on, we will talk about the limits of explaining the coevolution of gene and culture solely through the two types of positive feedback. This limit results from a special trait of positive feedback, especially the core positive feedback. First, let us look into the function and the endpoint of the positive feedback process through looking at marginal positive feedback.

The positive feedback process in the relationship between dairy production and lactase functions to create more lactase and provide cultural information about dairy farming within a group. However, under the assumption that there is a pretty consistent population within that group, there could not be a continuous increase of the entities who have lactase. The element that intervenes in positive feedback process is the frequency within the group rather than the complexity of lactase. Therefore, once the enzymes are spread in a group in a short period of time, the task of the positive feedback is completed. The culture of dairy farm, yet, can continue to develop, which will be another type of evolution than positive feedback. Positive feedback refers to a change in an aspect caused by a change in another aspect; however, the continuous development of the dairy farm indicates a cultural change without a change in the organisms.

In order to easily understand the fact that there must be an endpoint to positive feedback, one can look at a simpler example of positive feedback. The production of oxytocin and pain continuously increase through positive feedback. However, that increase does not continue forever. The pain disappears and the production of oxytocin decreases when a child is born. Similarly, the positive feedback relationship between albedo of the earth and glacier also stops after the glacier is all melted. The reason why the temperature continues to increase after the glacier melts is because it is affected by sources other than albedo. Positive feedback in nature helps a certain condition to quickly reach a certain level. In contrast, negative feedback process appears more often than positive feedback, and it serves as a mechanism to maintain homeostasis in organisms or in the ecosystem. A

typical example of a negative feedback is maintaining blood sugar level through insulin and glucagon. While negative feedback can be always continued for maintaining homeostasis, positive feedback must terminate and therefore is not a common process.

In regards to evolution of marginal traits, we have to examine not only positive feedback but also the cultural evolution following the feedback. However, a more important issue here is positive feedback which leads the evolution of human uniqueness. Even if we analyze the post-feedback cultural evolution process with the examples of marginal positive feedback, there is nothing we can say about the evolution of human uniqueness and what came after. As mentioned before, cultural evolution theory can be only complete when it explains the human uniqueness problem.

Traits of core positive feedback are not as simple as genes for lactase. For example, the genetic factor that is in charge of cooperative abilities is very complex and diverse; there is a spectrum that ranges from the simplest level to the most complex level. Then, does this mean that core positive feedback is free from the marginal positive feedback's problem of termination? If that was true, there would not be a mention of any problems in core positive feedback. No matter how complex the trait is, it can never be free from physical and bodily restrictions. In order for the cooperative abilities and social inferential skills to advance, there should be an improvement in both quantity and quality in the nervous system. However, the size and operation method of the brain is under a number of restrictions. For example, as the size of the skull increases in order to hold a bigger brain, there is a higher chance of death during childbirth for both mother and fetus.

The change of environment and the change of organisms may seem quite different. This is because the environmental change is much faster than the change of organisms. If Sterelny's core positive feedback process increases the differences from the information about the differences, a rapid change in the environment must result in a big change in organisms. Archeological evidence about human ancestors suggest that the environment changed dramatically when behaviorally modern human began to exist. Then, during that time, did humans experience a dramatic biological change? Even though anatomically modern human appeared way before behaviorally modern human, we cannot know the cognitive development of humans just with the anatomical equivalence between anatomically modern human and behaviorally modern human. However, there still are some questions of whether the physical and cognitive changes in an organism is still accompanied in response to the changes in the environment.

From fifty thousand years ago since the first appearance of a behaviorally moral human until now, there has been almost no case of biological change in the unique human traits. In contrast, the

environment experienced a rapid change after the fifty thousand years. Moreover, it may seem that the environmental change should be slower when the change in the organism experiences traffic, but that is not the case. Positive feedback loop often has problems in explaining the coevolution of cognition and environment.

### A new understanding of co-evolutionary theory

The dual inheritance theory and the niche constructionism apply the two types of positive feedback processes to deal with the relationship between culture and organism. As mentioned before, their approach to the co-evolutionary theory is not complete. Their concept of the coevolution is confined to positive feedback only; therefore, they cannot fully explain the cultural evolution after the feedback. The phenomenon between gene and culture has to be studied more broadly by expanding the concept of coevolution. Next we will talk about relationships other than positive feedback that can be included in the concept of coevolution. Those include symbiosis, competition, parasite, and indifference<sup>1)</sup>; these relationships not only exist between organisms but also between gene and culture.

#### 5.1. Symbiotic Relationship

Symbiosis is the most similar to the positive feedback process. It means that not only culture and organism work together to help change each other but also the two elements become one. Just as the symbiotic relationship between cells has evolved in the history of life, culture and organism can be completely merged together, which can form a cluster. A common example is a technology of combining a body part with a machine.

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1) Dennett has already divided the relationships between memes and organisms into three categories: parasites, commensals, and mutualists[20]. Our categorization differs from Dennett's in that ours has an extra category: competition. Some cultural variations, such as artificial intelligence, cannot be regarded as a just parasite on a host, and might compete equally as an independent actor with human in the near future. Because the point of our argument is the limit of co-evolutionary theory, so we will not elaborate on the categorization specifically in this paper.



## 5.2. Competition

The culture developed through positive feedback can also move in a harmful direction. Conflict between human and artificial intelligence in the future may be a stereotypical film material; in fact, however, it is likely to be fully realized in the near future. Ecological competition will be inevitable if there is a cultural entity that requires similar resources as humans. If these relationships appear, however, it is clear that such relationship is not positive feedback.

## 5.3. Parasitism

Parasitism consists of characteristics of both symbiosis and competition. Parasitism may seem like symbiosis at a glance; in fact, it is a relationship that one side is exploiting the other, reducing the goodness of fit in the future. An example would be a spread of a cultural item that has a harmful addiction to health. The behavior of smoking is often passed on because it seems stylish. However, smoking does not contribute in the evolution of organisms. Cases of suicide can also be seen as an extreme example of parasitism. Even by hearing about a celebrity's death or a suicide news, our chance of committing a suicide increases. A suicide of an individual exposes the other to the information about suicide; cultural information about suicide decreases the benefits of the genes.

## 5.4. Indifference

Besides the previous three aspects, there is a culture that spreads regardless of the genetic change. Humans cannot always be productive. The transfer of cultural change that takes place during consumption or during leisure time does not have a big influence in the organisms; however, it can spread or develop.

## Conclusion

Cultural evolution could be the most unique aspect of human uniqueness. That is because it chose a new method of evolution that creates its own selection process by organizing an environment from the original way of an organism's adaptation to the environment. Also, this cultural ability has

traveled with the evolution of human uniqueness. The co-evolutionary theory explains this concept with positive feedback, about how the various elements evolve together through exchanging causal and practical effects. The core positive feedback that Sterelny proposed and the marginal positive feedback investigated by other co-evolutionary theories are each responsible for a different type of traits. However, not only this positive feedback is unusual, but also it has an endpoint once it starts. Positive feedback in nature has a shorter duration than many other interactions. The cultural evolution in co-evolutionary theory efficiently explains the explosive evolution process of a short period of time; however, it often ignores other interactions. The concept coevolution should encompass the interaction of gene and culture after positive feedback. If it was a leap that culture became entangled with organisms to evolve to a complex form, it was another leap that the culture was released from the entanglement and interacted with the organisms in various forms.

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